# INFLUENCE OF RAINFALL, AIR TEMPERATURE, PHYSICAL AND CHEMICAL WATER PROFILES ON CYANOBACTERIA BIOVOLUME IN SLIM RIVER LAKE, PERAK, PENINSULAR MALAYSIA

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UNIVERSITI PENDIDIKAN SULTAN IDRIS

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FACULTY OF SCIENCE AND MATHEMATICS
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Thank you.

# ABSTRACT

This study aimed to identify the influence of rainfall, air temperature, physical and chemical water profiles on cyanobacteria biovolume in Slim River Lake, Perak, Peninsular Malaysia. Water samples were collected twice per month for 12 months in five sampling stations (S1-S5) to represent the lake's overall condition. Samplings were consistently conducted at the same time in the morning to reduce the influence of surrounding air temperature variations. The physical, chemical, and biological parameters were analysed according to American Public Health Association (APHA) standard methods. Rainfall and air temperature data were obtained from the Malaysian Meteorological Department. Data were successfully collected and the results indicated that Slim River Lake's physical, chemical, and biological water profiles were highly variable on a temporal scale. Total phosphorus, total nitrogen, chemical oxygen demand, chlorophyll-*a* and biovolumes of *Microcystis* spp. were recorded as 0.20-1.96 mg/L, 1.0-4.2 mg/L, 9.50-82.0 mg/L, 2.08-132.05 µg/L, $6.13\times10^{6}$- $1.65\times10^{8}$ $\mu m^3$ /mL, respectively. These parameters were recorded at levels exceeding the recommended limit values by National Lake Water Quality Criteria and Standards (NLWQS). Temporal fluctuations in physical, chemical, and biological profiles cannot be generalized into similar patterns. Rainfall and air temperature ranged as 36.3-642.5mm and 30.71-35.0$^{o}$C, respectively. Rainfall and air temperature explained up to 72.3% and 77.3% variation in lake water quality. Multivariate Principal Component Analysis (PCA) suggested that 71.5% of chlorophyll-*a* variation and 70.2% of *Microcystis* spp. biovolumes variation can be explained by changes in rainfall, air temperature, physical and chemical water parameters. In conclusion, this study successfully showed that the physical, chemical and biological profiles in the Slim River Lake are variable and influenced by the variability of local rainfall and air temperature. Moreover, parameters included in the PCA analysis can largely explain temporal changes of cyanobacteria biovolume. In implication, the study outputs are useful for lake quality assessment and rehabilitation strategy formulation to mitigate the impact of changes in physical, chemical and biological profiles.

# PENGARUH HUJAN, SUHU UDARA, PROFIL FIZIKAL DAN KIMIA AIR TERHADAP ISIPADU BIO SIANOBAKTERIA DI TASIK SLIM RIVER, PERAK, SEMENANJUNG MALAYSIA

## ABSTRAK

Kajian ini bertujuan untuk mengenal pasti pengaruh hujan, suhu udara, profil fizikal dan kimia air terhadap isipadu bio sianobakteria di Tasik Slim River, Perak, Semenanjung Malaysia. Sampel air dikutip dua kali sebulan selama 12 bulan di lima stesen pensampelan (S1-S5) bagi mewakili keadaan keseluruhan tasik. Persampelan dijalankan secara konsisten pada masa yang sama pada waktu pagi untuk mengurangkan pengaruh variasi suhu udara di sekeliling. Parameter fizikal, kimia dan biologi telah dianalisis mengikut kaedah standard Persatuan Kesihatan Awam Amerika (APHA). Data hujan dan suhu udara diperoleh daripada Jabatan Meteorologi Malaysia. Data telah berjaya dikutip dan hasilnya menunjukkan bahawa profil fizikal, kimia dan biologi air Tasik Slim River berubah-ubah pada skala temporal. Jumlah fosforus, jumlah nitrogen, permintaan oksigen kimia, klorofil-*a* dan isipadu bio *Microcystis* spp. direkodkan masing-masing sebagai 0.20-1.96 mg/L, 1.0-4.2 mg/L, 9.50-82.0 mg/L, 2.08-132.05 µg/L, $6.13\times10^{6}$- $1.65\times10^{8}$ $\mu m^3$ /mL. Parameter ini direkodkan pada tahap melebihi nilai had yang disyorkan oleh Kriteria dan Piawaian Kualiti Air Tasik Kebangsaan (NLWQS). Perubahan profil fizikal, kimia dan biologi pada skala temporal tidak boleh digeneralisasikan kepada corak yang serupa. Hujan dan suhu udara masing-masing berjulat 36.3-642.5mm dan 30.71-35.0$^{o}$C. Hujan dan suhu udara menjelaskan sehingga 72.3% dan 77.3% variasi dalam kualiti air tasik. Analisis multivariat *Principal Component Analysis (PCA)* mencadangkan bahawa 71.5% variasi klorofil-*a* dan 70.2% variasi isipadu bio *Microcystis* spp. boleh dijelaskan oleh perubahan hujan, suhu udara, parameter fizikal dan kimia air. Kesimpulannya, kajian ini berjaya menunjukkan bahawa profil fizikal, kimia dan biologi di Tasik Slim River adalah berubah-ubah dan dipengaruhi oleh faktor hujan dan suhu udara. Tambahan pula, parameter dalam analisis PCA sebahagian besarnya boleh menjelaskan perubahan temporal isipadu bio sianobakteria. Implikasinya, hasil kajian ini berguna untuk penilaian kualiti tasik dan penghasilan strategi pemulihan untuk mengurangkan kesan perubahan dalam profil fizikal, kimia dan biologi.

# TABLE OF CONTENTS

# LIST OF TABLES

# LIST OF FIGURES

# LIST OF ABBREVIATION

| | |
|---|---|
| ANOVA | Analysis of Variance |
| GLM | Generalised Linear Multivariate |
| GLM-AED | General Lake Multivariate- Aquatic Eco - Dynamics |
| BRT | Boosted Regression Tree (Method) |
| EPA | Environmental Protection Agency |
| SPSS | Statistical Package for the Social Sciences |
| IR LED | Infrared Light Emitting Diode |
| MPF | Maximum Principle Flux |
| MSL | Mean Sea Level |
| NGS | Next Generation Sequencing |
| NIS | Nikon Imaging Software |
| NLWQS | National Lake Water Quality Standards |
| PCA | Principle Component Analysis |
| SE | Standard Error |
| TLI | Trophic Level Index |
| TSI | Trophic State Index |
| UKM | University Kebangsaan Malaysia |
| USA | United States of America |

USEPA United States Environmental Protection Agency

# LIST OF APPENDIX

# CHAPTER 1

# INTRODUCTION



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## 1.1 Study Background

Lake is a confined water body completely encircled by land with no immediate connection to the sea except by a stream or river that sustains or drains the lake (Luo et al., 2020). In addition to wetlands and ponds, lakes are lenticular or standing water system with a long water retention period and complex population (Huang et al., 2015). Lakes are categorized into natural lakes and human made lakes (Huang et al., 2015). Lake has various services,

including water source, drainage, food supply, flood control, hydroelectricity generation, transportation, recreational, and eco-tourism (Huang et al., 2015; Kertész et al., 2019). To date, deterioration of the lake's water quality has been an alarming problem in most developing tropical countries. Lakes receive various pollutants, primarily from land use changes, domestic activities, and farming (Kertész et al., 2019). Due to the detrimental impact on environmental, economic, and health aspects, lake degradation has been a significant concern recently and was addressed as a serious issue both locally and globally.

Agricultural intensity and dramatic changes to biogeochemical cycles have profoundly impacted anthropogenic inputs of nutrients on the Earth's surface (Elsworth et al., 2020). Furthermore, between 30 to 50 percent of the Earth's surface has been transformed, typically resulting in more efficient transport pathways for excess nutrients to reach surface waters (Baulch et al., 2019). Consequently, a phenomenon mainly triggered by the excess nutrients in surface water termed eutrophication, has become a growing concern for lake degradation.

Eutrophication is a process by which primary productivity increases within a water body to the point where the ground surface has built up. Eutrophication can be divided into two categories; natural and cultural. The process of natural eutrophication happens gradually and very slowly in geological time. Meanwhile, anthropogenic activities can dramatically accelerate it, commonly known as human-made, cultural, and industrial eutrophication (Bhagowati & Ahamad, 2018). In particular, industrial and domestic waste

discharge in lakes causes hypereutrophic state characterised by excessive nutrient availability, low light penetrability, and frequent algal blooms (Du et al., 2019).

In eutrophic lakes, their natural ecological balances are often disturbed by the changes in the phytoplankton community. Phytoplankton is often dominated by cyanobacteria. Cyanobacterial bloom is a term used to describe a lake ecosystem condition where its phytoplankton community is mainly dominated by cyanobacteria (Shan et al., 2019). Cyanobacteria (also referred to as blue-green algae) is a photosynthetic bacteria present in most lake water columns. Cyanobacteria can quickly proliferate to form large populations on the water, forming blooms (Josué et al., 2019). Cyanobacterial blooms in a freshwater lake ecosystem primarily consisted of *Microcystis* spp, *Anabaena* spp or *Cylindrospermopsis* spp. In contrast, in the marine ecosystem, *Lyngbya* spp, *Synechococcus* spp. and *Trichodesmium* spp. were often dominated (MohaMaD et al., 2016). Cyanobacterial blooms affect human health worldwide due to some cyanobacteria's ability to release toxins (Krztoń et al., 2019). Exposure to cyanobacteria toxins such as microcystin, presents a severe health hazard, including poisoning, liver failure, tumours, and death to livestock, wildlife, and humans (Preece et al., 2017). In Malaysia, concerns about the effects of lake eutrophication have increased in recent years, requiring the formulation and implementation of laws and programs for its prevention (Tang, 2019).

At present, significant efforts have been made to investigate the factors affecting the lake's eutrophication. These activities were taken to prevent further lake degradation and ensure adequate management and remediation efforts to restore its stability (Sharip et

al., 2014; Vogt et al., 2018). Nevertheless, complex and inter connected impacts of natural factors (i.e., rainfall, climate change), urbanisation, and industrialisation, have become the key challenges and obstacles in maintaining the lake's water quality and ecosystems (Shahabudin & Musa, 2018). Moreover, the complexities of eutrophication within the ecosystem has presented challenges in developing the best eutrophication management strategy (Descy et al., 2016).

Local weather and hydrologic conditions are among the factors that may influence the eutrophication responses as they can alter nutrient loads into the lake water (Vinçon Leite & Casenave, 2019). Malaysia's weather is influenced by the equatorial climate, characterised by hot and humid weather all year round. The annual weather variability is closely associated with the southwest and the northeast monsoons, which occurred between April to September and October to March, respectively (Tang, 2019). The Southwest monsoon has drier weather with lower rainfall relative to the northeast monsoon. To date, the impacts of local rainfall and air temperature variabilities on water quality, eutrophication progression, and cyanobacteria are still scarce and needs furtherance. The local rainfall and air temperature refer to rainfall and air temperature associated with a particular locality or area of concern. In this study, the local rainfall and air temperature were obtained from Felda Sungai Behrang, a weather monitoring station in Slim River, Perak.

## 1.2 Problem Statement

Eutrophication and cyanobacteria in freshwater lakes can cause profound implications, mainly foul odours, water column deoxygenation, toxicity, destruction of aquatics life, and disturbance to food chain stability (Sinang et al., 2015). It has been documented in the literature that high nutrient availability and temperatures tend to mutually enhance eutrophication symptoms, such as the dominance of cyanobacteria, floating plants, and massive loss of underwater flora and fauna (Scholz et al., 2017).

The existing knowledge on eutrophication suggests that locally unique or site specific environmental factors may also influence eutrophication progression. The variability of site-specific environmental factors composed of physical, chemical and biological water profiles may be more profound on a temporal basis in a small lake and a spatial basis in a large lake ecosystem. Understanding the changes or variability in lake water column's physical, chemical, and biological profiles is crucial in understanding lake eutrophication progression. This information is important for lake eutrophication management. Slim River Lake, a small shallow lake known as an iconic landmark to Muallim district, is chosen for this study. This is due to the need for the local authority to establish a eutrophication management plan for this lake. However, a recent and comprehensive study on Slim River Lake's physical, chemical and biological water profiles is unavailable. Slim River Lake's water quality assessment was performed in 2012 (Nayan et al., 2012), but the study was undertaken primarily to determine its suitability for recreational purposes. Thus, inadequate data regarding Slim River Lake's physical, chemical, and biological water

profiles and how it changes over a temporal basis have caused difficulties in enforcing its management plan.

On the other issue, the physical, chemical, and biological water profiles in a lake may largely depend on the local rainfall and air temperature patterns. The local rainfall and air temperature refer to rainfall and air temperature associated with a particular locality or area of concern. According to the previous study, rainfall distribution and frequency significantly affect eutrophication (Deng et al., 2019). Extreme rainfall caused an increase in nutrient loadings due to surface runoff and consequently led to the water column's desertification. According to a study conducted in Lake Falemprise, Wallonia, the dominance of phytoplankton genera during eutrophication was highly influenced by weather variability (Descy et al., 2016). During warm and stable local weather, cyanobacteria such as *Aphanizomenon flos-aquae* dominated the lake and other phytoplankton groups (chlorophytes, diatoms, chrysophytes, and euglenophytes) due to the stratification of the water column and increased light intensity (Descy et al., 2016). Nevertheless, the lake was dominated by *Planktothrix agardhii* during cold and windy weather due to vertical mixing and phosphorus release from sediment. In addition, it was also reported that the influence of climatic factors in different seasons might surpass the effect of nutrient availability in the water bodies (Deng et al., 2019).

Despite numerous studies conducted in four-season countries, the influence of local weather patterns on a lake's eutrophication symptoms has never been discussed locally in Malaysia, including Slim River Lake. Additionally, there is an inadequate assessment of cyanobacteria in eutrophic lakes, especially in lakes used for recreational purposes such as

Slim River Lake. Previous studies on eutrophication-related issues in Malaysian lakes mainly focus on nutrients, phytoplankton, and macrophyte variabilities (Othman et al., 2014; Sharip et al., 2016; Rizhinashvili, 2017). Due to the current information gap, the temporal variability of eutrophication symptoms, mainly cyanobacteria, remain widely unknown. As a result, the period of high cyanobacteria biomass, which imply a possible period of high cyanobacteria toxin, cannot be explained.

In terms of the proposed mathematical analysis, many previous studies have also proposed mathematical analysis to study climatic factors' potential impact on cyanobacteria succession in eutrophic lakes (Ho et al., 2019; Stauffer et al., 2019). In general, these studies' analysis show that an increase in cyanobacteria's relative biovolumes was related to increased water temperature (Elliott, 2012; Reid et al., 2019; Mantzouki et al., 2016). However, their proposed analyses did not use local air temperature or rainfall parameters. Therefore, a multivariate regression analysis that includes local rainfall and air temperature is needed to explain the variability of cyanobacteria and phytoplankton in an aquatic ecosystem, especially in our local setting.

Thus, to address the gaps mentioned above, this study was conducted to establish the physical, chemical and biological profiles and examine its temporal variability in the Slim River Lake. The temporal variability of physical, chemical and biological profiles was examined against the variability of local rainfall and air temperature patterns. Furthermore, cyanobacteria's succession in the study lake was against the local rainfall, air

temperatures, physical and chemical profiles. This study also assesses phytoplankton and cyanobacteria diversity through microscopic analyses. Besides fulfilling the future lake management need, a study conducted in Slim River Lake also serves as a proxy better to understand the response of a small shallow lake to the changes in local rainfall and air temperature patterns.

### 1.3 Study Objectives

The ultimate aim of this study was to characterize the influence of rainfall, air temperature, physical and chemical water profiles on cyanobacteria succession in a small shallow lake ecosystem. Specifically, the objectives of this study are as follows:

1. To determine the temporal variability of lake's water physical, chemical and biological profiles in Slim River Lake area.

2. To determine the influence of rainfall and air temperature on the lake's water physical, chemical, and biological profiles.

3. To develop a multivariate principle component analysis (PCA) to explain the cyanobacteria biovolume based on rainfall and air temperature patterns, in lake chemical, and physical profiles.

### 1.4 Study Questions

This study was designed to answer the following research questions:

1. What are the temporal variabilities of lake's water physical, chemical and biological profiles in Slim River Lake area?

2. How does the rainfall and air temperature influence variabilities of physical, chemical and biological profiles in Slim River Lake area?

3. How much of the cyanobacteria biovolume can be explained from rainfall and air temperature patterns, in lake chemical and physical profiles, based on the multivariate principle component analysis (PCA).



### 1.5 Study Hypotheses

1. Lake's water physical, chemical and biological profiles in Slim River Lake are highly variable on a temporal basis.
2. The lake's water physical, chemical and biological profiles in Slim River are influence by local rainfall and air temperature.
3. The biovolume of cyanobacteria can be explained by the multivariate principle component analysis (PCA) based on rainfall and air temperature patterns, in lake chemical and physical profiles in the lake.

## 1.6 Significance of the Study

This study elucidated the influence of rainfall and air temperature variability on the water quality physical, chemical and biological profiles of a lake regarding contaminations exposure and cyanobacteria growth. Data and information obtained in this study provided a clear picture of the significant role of rainfall and air temperature factors and their relationship with other water parameters that may potentially impact the lake's condition and aquatic life diversity. It thus enables certain integrated lake management systems and maintenance to be planned during the rainy-wet and sunny-dry seasons (Ben Eledo et al., 2017). Therefore, the deterioration and degradation of the lake's water quality and ecosystem can be prevented. The study significantly contributes to preventing and reducing exposure to toxic cyanobacteria in the lake, especially at Slim River Lake. This lake is an essential site for recreational activities, including fishing and drinking water sources for nearby livestock farms. In addition, this study is essential as there is a call for more scientific data on cyanobacterial bloom, diversity, and toxicity to draw more awareness on this disturbing problem from the Malaysian scientific community, specifically and globally (Jung et al., 2015). The period of toxic cyanobacteria blooms and toxins production can pose a great threat to the animals and humans who contact the contaminated lake water. Therefore, explaining the most probable period associated with high toxic cyanobacterial biovolume can reduce the risk of exposure through appropriate awareness-raising and advice to the local communities. Moreover, the statistical multivariate regression analysis obtained can explain the occurrence of cyanobacterial bloom in other similar eutrophic lakes in Malaysia or other countries with a similar climate, such as Indonesia and Thailand. Slim River lake is a human made recreational lake built from the former ore mining sites. It has

been extensively used for fishing, leisure, sport, and social gathering for the community of Muallim District, Perak. It receives high loads of nutrients primarily from surface run-off and discharges from the nearby farm, contributing to its eutrophication problem.

This study contributes to the knowledge and data regarding the temporal variability of this lake's physical, chemical, and biological profiles. This reflects its health status and contamination of the ecosystem. Besides, data on the genetic community obtained through Next Generation Sequencing (NGS) revealed the presence of cyanobacteria this lake, which justify the need for a proper eutrophication control and health risk assessment by the local authority.



## 1.7 Scopes and Limitation

This study only focused on the evaluation of water quality (physical, chemical, and biological properties) and cyanobacteria diversity and biovolumes in Slim River Lake, Perak state, Malaysia (3º 49' 26.688" N; 101º 24' 30.6216" E). So, in this thesis, this lake will only be referred to as Slim River Lake. This man-made lake is chosen as a proxy for this study as it is a small shallow lake and highly used by locals for recreational and leisure fishing activities. The lake is surrounded by agricultural lands, mainly oil palm and a cow farm. From the previous study conducted by Aeriyanie et al. (2021), it was revealed that the Slim River Lake has a high level of nutrients with occurrence of high total phytoplankton and cyanobacteria biomass. Therefore, this lake is very suitable for this study.

In this study, the local rainfall and air temperature refer to the measurements at the closest weather monitoring station which located in Ladang Sungai Behrang. The distance of this weather monitoring station to the study lake is approximately 10 km. The rainfall and air temperature data were obtained from the Department of Meteorology in Perak state.

There are several limitations are identified and described as follows:

i. The water quality analysis is performed in one lake with five sampling sites to represent the lake's overall condition and is limited to the sampling duration of 12 months.
ii. Due to certain limitations during the study, data collection in S4 and S5 was started later than S1, S2 and S3.
iii. The physical, chemical and biological profiles analysed refer to water temperature, turbidity, pH, total nitrogen (TN), total phosphorus (TP), dissolved oxygen (DO), chemical oxygen demand (COD).
iv. The biological parameters were included chlorophyll-*a* and biovolumes of *Microcystis* spp., because they represented most abundance genera of cyanobacteria in Slim River Lake.

## 1.8 Thesis Organisation

The thesis is organised into six chapters, as summarised in Figure 1.1. Chapter 1 commences with an introduction to the background of the study. This chapter includes the problem

statement, study objectives, study questions, and significance of the study. Moreover, this chapter also explains the scope and limitations of the study.

Next, Chapter 2 portrays a literature review of previous studies from relevant sources that have contributed to the intellectual advancement of the current issues, findings, theories, and debates related to the influence of local rainfall and air temperature on the lake's water quality and cyanobacteria of the present study. This chapter offers a conceptual description, organisational pattern, and critical assessment of these previous works concerning the current study being investigated.

The methodology used in this study is presented in Chapter 3. The materials and methods utilised are described in this chapter. Chapter 4 contains all the results and findings of this study. Chapter 4 is divided into three sections based on the research objectives; i. Temporal variability of physical, chemical and biological profiles, in Slim River Lake, ii. Influence of local rainfall and air temperature on the lake's physical, chemical, and biological profiles, and iii. A multivairate principle component analysis (PCA) to explain the biovolumes of cyanobacteria from local rainfall and air temperature patterns in lake chemical and physical profiles. Chapter 5 focuses on the discussion of results according to the stated objectives. In the end, Chapter 6 concludes the thesis and provides recommendations for future study.

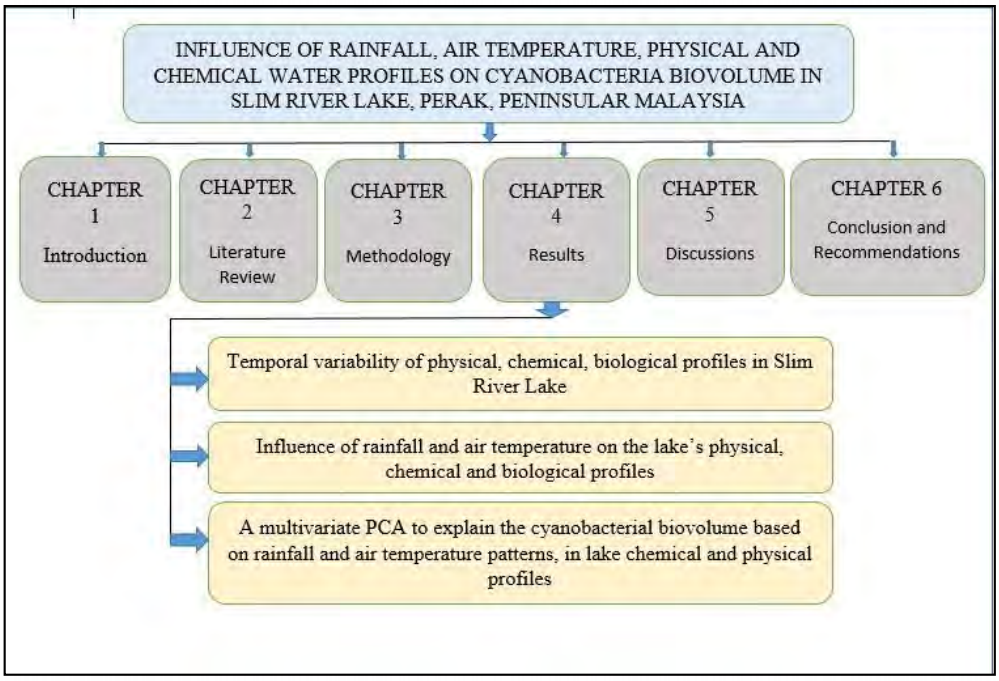


*Figure 1.1*. Thesis organisation